Assessing a Research/PD Model in Patterning and Algebra

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Abstract

In this study, researchers and teachers worked together to evaluate a series of lessons developed to foster student understanding of linear functions. To bridge the research-practice gap, we developed a Research/PD Model of professional development that included teachers as research participants. Our research questions were 1) will participation in the PD program increase teachers' pedagogical content knowledge in patterning and algebra?; 2) will participation in the PD program influence teacher efficacy?; and, 3) what is the role of teacher enactment in the professional development of teachers? We assessed the Research/PD model's effectiveness through teacher and student outcomes. Measures included quantitative (surveys and tests) and qualitative (observations, interviews and field notes) data collection sources. The results clearly indicated that the Research/PD model had an impact on teacher learning and efficacy. By charging teachers with the role and responsibility of implementing the lesson sequence and critiquing its effectiveness, teachers increased their own understanding of, and success with, teaching patterning and algebra. Our approach supported teacher development in three ways. The PD program supported teachers *for* practice (through experiencing an inquiry-based lesson sequence), *in* practice (feedback during formal and informal classroom visits), and *from* practice (opportunities for teachers to debrief, which then informed the refinement of lessons for future implementation). This study underscores the value of involving teachers in the research process.

Introduction

Over the last 50 years, researchers have studied the importance of teacher professional development (PD). What teachers know and are able to do is a key factor influencing student learning (Fullan, Hill, & Crevola, 2006). However, there is a lack of empirical research on the effects of PD on teacher learning, particularly with respect to developing classroom knowledge and improving practice (Hill, 2004), which are crucial indicators of success (Fishman, Marx, Best & Tal, 2003). Our goal was to develop a Research/PD Model that embedded professional development within a longitudinal research program for two reasons: 1) to continue to evaluate an innovative approach to teaching patterning and algebra in elementary grades; and, 2) to assess the effects of including teachers as collaborative partners on their development as mathematics educators. To this end, we examined teacher learning and its links to teacher participation (with a critical focus on teacher enactment), teacher knowledge, and classroom practice.

Background to patterning

Patterning activities have long been recommended as a means of supporting students in developing an understanding of the relations among quantities that underlie mathematical

functions. However there is substantial evidence suggesting that with current instruction, identifying the link between patterns, generalized rules, and algebraic representations is difficult. Analysts (e.g., Lee, 2006; Mason, 2006) who have studied patterns and generalizing suggest that it may not be patterning problems per se that are difficult, but rather the way that they are presented to students and the limitations of the teaching approaches used. Although patterning problems may be presented initially in a variety of formats (geometric, tabular, and narrative), the tendency of most instruction is to prioritize the numeric/arithmetic aspect of patterning activities (Noss & Hoyles, 1996). This numeric approach to pattern learning diminishes the potential for students to recognize commonalities in mathematical relationships across multiple representations, and obscures the underlying functional relationship of the pattern because the pattern rule becomes a sequence of arithmetic operations derived numerically in isolation from the context of the problem. Students do not perceive the need to understand the mathematical structures and relationships underpinning pattern rules, so these activities do little to expand their understanding, ability, or interest in finding and justifying meaningful general rules (functions).

In response to this, the first author conducted a series of experimental studies in Grade 4, 5 and 6 classrooms with the goal of designing new approaches to pattern learning that emphasize multiple representations (geometric, graphic, and symbolic) as a means of supporting children's developing understanding of mathematical functions. Based on Case et al.'s research methodologies (e.g., Moss & Case, 1999) the instructional sequences and curriculum materials were aligned with theoretically based learning trajectories, and then tested in a variety of classrooms. The inquiry-based lesson sequence was designed to encourage meaning making through the use of mathematical discourse, multiple representations, manipulatives, and rich open-ended tasks. The three-year research program was iterative, in that results from each year informed the design of subsequent instruction. Results have demonstrated positive outcomes based on the lesson sequence for this kind of instruction for all students, including those who have demonstrated very low math ability (e.g., Beatty & Moss, 2006).

Linking research, professional development, and teacher learning

The study for this paper took place in the third year of the research program. At this point, the content of the lesson sequences had been evaluated, but there still remained questions with respect to best practice implementation. Therefore, we invited experienced teachers to participate in the PD program component of the Research/PD Model as collaborative partners to

further assess the quality and functioning of our experimental patterning and algebra lesson sequence. Simultaneously, the researchers were testing this Research/PD Model to see whether it supported teachers in developing their pedagogical content knowledge, practice, and efficacy (teachers' confidence that they have the ability to promote student learning) (Bandura, 1977). Teacher efficacy is an important construct because it has been associated with variables such as teachers' willingness to adopt innovations, teachers' classroom management strategies, time allocated to teaching challenging subjects and topics, and student achievement. . The pivotal role of teacher enactment (Fishman et al., 2003) - implementation of the content and pedagogy - is central to our model (see Fig. 1). This paper focuses on the shaded part of the model in figure 1 in order to explore the relationships between implementing a Research/PD model designed to develop teacher content and pedagogical content knowledge, and increase teacher enactment of a new curriculum and teacher efficacy.

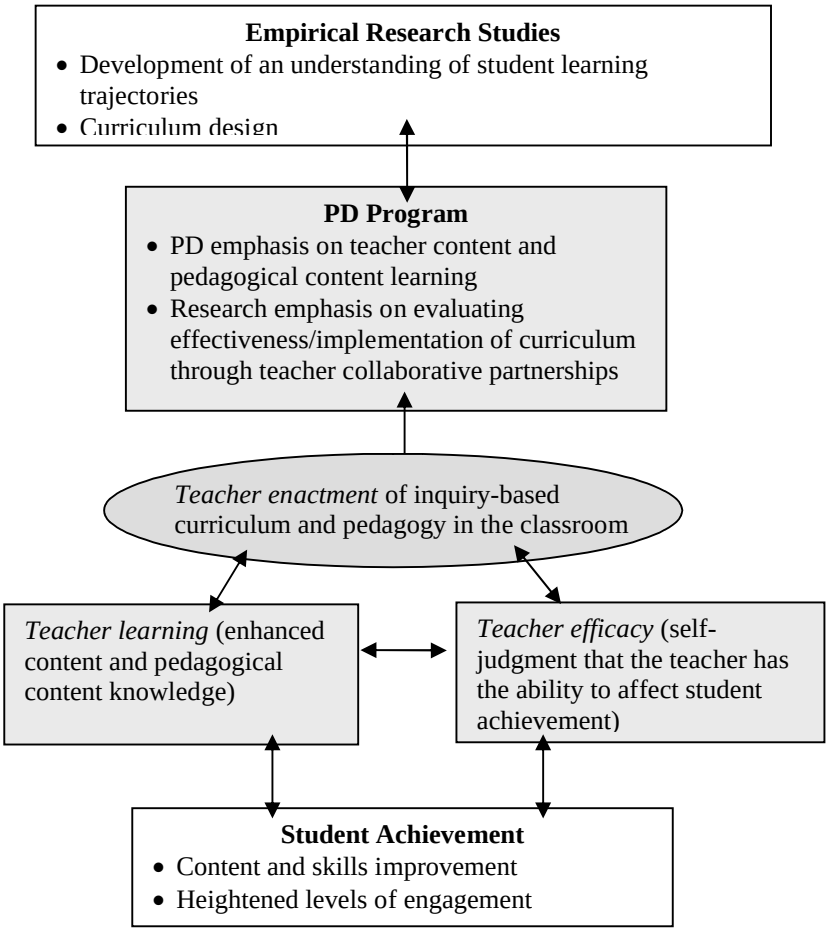

Fig 1. *Research/PD Model*

Research questions for this study:

1) Will participation in a PD program based on a specific lesson sequence increase teachers' pedagogical content knowledge in patterning and algebra?
2) Will participation in the PD program influence teacher efficacy?

3) What is the role of teacher enactment in the professional development of teachers?

The study borrowed from Hill's (2004) model of professional development for PD design and implementation. Hill cites research outlining conditions for effective professional development, stating "teachers can and do respond to professional development…when they have adequate opportunities to learn and when those opportunities are focused on content; grounded in artifacts of practice, such as curriculum, videotape, or student work; supported over time…"(p.217). Figure 2 outlines the connection between Hill's recommendations for effective PD design and specific components of our PD program.

Professional development standards	PD components
Active learning – teachers construct meaning through inquiry or analysis to build their own understanding	Participated in the lesson sequence *as learners*, then implemented in their own classrooms
Examples from classroom practice – teachers look at student work and related curriculum materials	Teachers viewed student work (artifacts, videotapes etc) from research study. The teachers also focused on student learning in their own classrooms, and in the classrooms of other participating teachers.
Collaboration – teachers work together	Collaboration during the PD sessions, and during implementation of the lessons.
Modeling – professional developers model constructivist teaching practices	Researchers modeled not just pedagogy and strategies, but whole sequence of lessons designed to support development of conceptual understanding.
Reflection, practice, feedback – teachers have the opportunity to return to their classrooms, try new ideas, and receive follow up support	Three sessions during which teachers brought back classroom results/experiences to share in focus group sessions.
Focus on content – teachers have opportunities to increase knowledge of the subject matter and pedagogy	Inservice focus was to develop content knowledge specifically in the domain of patterning and algebra, and an understanding of children's thinking in this area.
Focus on student learning – teachers engage in activities that strengthen their understanding of how children learn patterning and algebra	By engaging in learning and teaching the lesson sequences, teachers were supported in how to understand student thinking .
Teacher choice – teachers choose to participate and make choices based on self-identification of needs	Participation in this study was voluntary. Teacher choice in terms of subject matter, lessons etc were not offered. However, teachers were encouraged to modify lessons (and share modifications) as needed.

Figure 2: Hill, H.C. (2004). Professional development standards and practices in elementary school mathematics. *Elementary School Journal*, 104(3), 215-231 Matched to our PD program.

We also used Fishman's 2003 model to evaluate the outcomes of the PD program, specifically: examining the links between teacher participation and enactment in classrooms; and changes in teacher knowledge and student outcomes.

Methodology

Participants

Fourteen experienced grade 5 teachers and two preservice teachers from a mid-sized district school board participated in the study.

Five full-day PD Sessions (over 4 months).

The structure of each session followed the same format: Each individual lesson of the sequence was taught to the teachers, so that they could develop their own content knowledge about patterns, and to model lesson pedagogy. After each lesson, teachers engaged in a researcher-led debrief session, during which the critical learning points were identified, and teachers reflected upon their own experiences with the activity. Next, videotape of student learning from the larger project was shown, so that the teachers would observe examples of different levels of student thinking. The print materials that accompanied the lessons included outlines of the activities, key questions to probe for student understanding, photographs of student artifacts, and sample transcripts of student thinking. We also provided each teacher with a class set of manipulatives.

The initial two-day training session was held prior to implementation of the lesson sequence. During this session teachers were introduced to the larger Patterning and Algebra research project, and provided with an overview of the lesson sequence, with a focus on the developmental learning trajectory, and the underlying rationale for the sequence.

In session 2, 3 and 4 – which took place during the time period when teachers were implementing the lessons in their classrooms – participants debriefed in small focus groups. During these videotaped sessions, which were led by the board mathematics consultants, the teachers were asked to critique the lessons in terms of content and implementation, and with respect to student learning. We were also interested in any modifications the teachers made. Our need for teacher expertise and feedback meant that the teachers were accountable for the implementation of the lessons in their classrooms between PD sessions.

Measures

In this study we wanted to evaluate the outcomes of teacher participation and examine the effectiveness of the Research/PD Model. Quantitative measures included teacher efficacy pre and post surveys (Tschannen-Moran & Woolfolk Hoy, 2001. Qualitative measures, included teacher pre and post pedagogical content knowledge surveys, transcripts of 16 focus group

interviews, teacher program evaluation forms, and field notes of classroom observations (four per teacher). These were used to critically examine the process of teacher change. Quantitative and qualitative data were analyzed independently in an embedded mixed methods design (Creswell & Plano-Clark, 2007).

Results

This paper reports on the findings related to teacher learning in the form of teacher pedagogical content knowledge development and teacher efficacy.

Teacher efficacy

Teacher efficacy, the extent to which teachers believe they will be able to bring about student learning, was measured at the beginning and end of the study using 12 items adapted for mathematics teaching from Tschannen-Moran and Wolfolk Hoy (2001). The population sample was small and therefore reliabilities are less stable than would be with a larger sample. Nonetheless, the data gave us one method of determining whether participation in the program had an impact on teachers' confidence in their abilities to affect student learning. There were statistically significant increases in teachers' beliefs about their ability to engage students in mathematics learning, ($t(13) = -1.35, p = .02$). An additional 20 items designed to measure attitudes and practices in teaching math indicated that teachers' scores moved toward a reform-based stance on the posttest, ($t(13) = -2.18$, $p = .049$).

Focus group interview transcripts and field notes also indicated increased teacher efficacy. For example, Janet discovered through the study that "the younger kids can handle a much more complicated understanding level than we thought they could." (Whole group transcript, 4.5) suggesting that her estimation of student ability to learn had changed. George described his new found commitment to using innovative teaching strategies once he observed the quality of student learning and engagement:

> I think we really bought into it because we're seeing how the kids would learn. I may have been in a workshop or two that I've just filed, basically I mean I went there, I kind of listened and I kind of put it away. I don't know, maybe I'm the only one in the board that's done that (laughter). The way that this is laid out: lesson 1, lesson 2, with those key questions - I always kept going back, did I ask that question? That's when I really bought into it (Whole group transcript, 4.5)

Adeleine described how seeing the students gain confidence increased her confidence to implement new strategies as a mathematics teacher:

> The students have been engaged, and have a high level of understanding. They were building patterns, and some were done quick (snaps) I thought 'some of the kids are done, some aren't, what should I do?' So I asked them to write all the rules for the patterns that they saw, which was really, really good because they all wrote in pairs and the level of understanding that came out of that blew me away. For some of them it was phenomenal, it was really good. I would incorporate doing this with other lessons too, they're showing me what they understand, it's really good. (Focus group transcript, 3.2)

Teacher pedagogical content knowledge

Results of the pedagogical content measure indicated an increase in teacher knowledge. On the pretest, teachers offered general strategies for problem solving e.g. asking students to explain their thinking, or using an ordered table of values. In the posttest, teachers advocated the use of multiple representations including pattern building, graphing, and finding and applying explicit composite rules. In addition, answers relating to graphs of linear functions showed clear gains in *content* knowledge, for example, the relationships between numeric/symbolic and graphic representations, e.g., the coefficient and slope of a line, and the constant and y-intercept.

Teachers also reported increased confidence in adopting a student-directed approach that included rich classroom discussion, use of manipulatives, and open-ended tasks. The pedagogical content knowledge learned through implementing the lesson sequence generalized to other math domains:

> "So I am comparing teaching algebra to fractions because the kids are so successful in the patterning work and able to explain it…if I can use the same approach with fractions, getting out the manipulatives and doing the group work and the modeling, maybe they'll have the same foundation for fractions…laying down the conceptual base so students have a solid understanding." (Field notes 4.2).

Teacher engagement in math teaching and ownership of the lesson sequence increased over the duration of the study based on classroom observation data (Obs 1-51). Teachers attributed these increases to (in order of ranked importance): quality of the lesson materials provided, opportunities to practice and discuss the lessons during PD sessions, and enacting/implementing the lesson sequence in the classroom (teacher evaluation forms).

Discussion

The findings have led to a confirmation of the hypothesized model of figure 1 for this study: We found that teacher engagement in high quality PD (Hill, 2004), combined with accountability for the enactment of the proposed lesson sequence, resulted in increased teacher

confidence to take risks with innovative teaching strategies and increased expectations of their abilities to positively influence student learning.

The results clearly indicate that the Research/PD Model had a positive impact on teacher learning. By charging teachers with the role and responsibility of implementing the lesson sequence and critiquing its effectiveness, teachers increased their own understanding of, and success with, teaching patterning and algebra while their students also gained increased understanding. Student mastery experiences then enhanced teachers' feelings of efficacy as the study progressed. This in turn increased teacher commitment to implementing the lessons and participating in a professional collaborative learning experience. Teachers' reported changes in practice extended beyond patterning and algebra, to a recognition of the importance of developing conceptual mathematical understanding through the use of an inquiry-based approach.

In summary, teachers began to conceptualize the teaching and learning of mathematics as a dynamic, creative endeavor, both for students:

> They are so engaged – and every single group was focused on the mathematics, which we know doesn't always happen in the classroom. (focus group 3.2)

and for themselves:

> And I'm really thinking that this is what math is all about, even as a teacher to get to the point where you can't wait to teach these math classes because they are so much fun and because there's a point where you *know* one of the students is going to do something or say something really incredible and – *out there* – and you're going to go 'What? You are opening up a little part of my brain!' and the more you see your kids building confidence, the more confidence you have as a math teacher." (focus group, 3.4).

Sustainability of shifts in teacher practice and conceptions of math teaching and learning is promising as all of the teachers in the study have continued their professional development in self-directed study groups with support from the board consultants and researchers.

> I just – I want to know we can continue to do this – meet and discuss like this, and keep learning deeply about math teaching. I feel like I need to keep learning and growing with everyone, with all of us thinking about this and talking it through. This is the most important thing for me…(focus group 4.4).

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